Observations of Planet Eros from Photographs taken with the 30-inch Reflector of the Thompson Equatorial at the Royal Observatory, Greenwich.

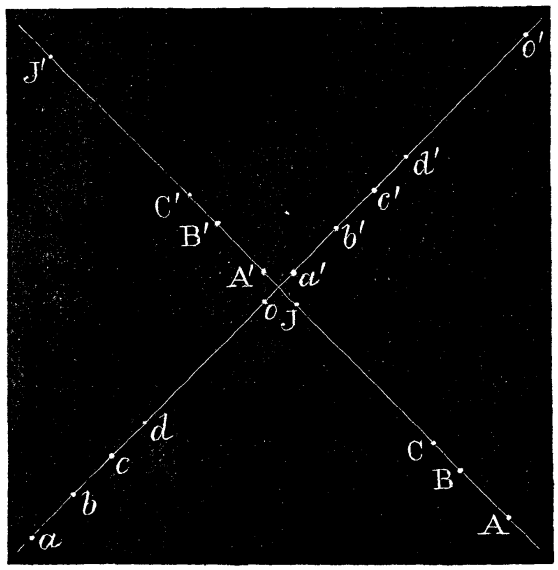
(*Communicated by the Astronomer Royal.*)

Photographs of planet *Eros*, on which the position of the planet is shown with sufficient distinctness for accurate measurement, have been obtained with the 30-inch reflector on twenty-four nights between 1898 September 20 and 1899 March 31. Ilford "special rapid" plates were used, and the exposure usually given was five or six minutes. On twelve nights two exposures were made on the same plate, and on six nights two separate plates were obtained. On two nights (February 28 and March 14) short exposures of 40 seconds were also given, in order to obtain smaller images of the "reference stars" for use in determining the plate constants. In the later photographs the electric hand control was used to correct the large motion of the planet in right ascension, as the trail of the planet was too faint to be distinctly measurable when the equatorial was driven at a sidereal rate.

Réseaux have been printed on all the photographs except those taken on September 20, 21, 23, and October 3, and rectangular coordinates of the planet and of the reference stars have been measured in exactly the same way as for the astrographic photographs. The positions of the reference stars have been derived when possible from the catalogues of the *Astronomische Gesellschaft*, those between 5° and 15° N. having been kindly supplied in manuscript by Dr. Bruns, the Director of the Leipzig Observatory, and those south of the Equator from the Ottakring Zone Observations for *A.G.C.*, the Karlsruhe Observations, the Radcliffe Catalogue, 1890, and Schjellerup's Catalogue for 1865.

The images of the stars at some distance from the centre of the field show considerable *coma* away from the centre. This introduces some uncertainty as to the position of the optical centre of the images, and it was therefore necessary to examine the distortion of the field. For this purpose a plate was exposed four times on the *Pleiades* showing two lines of stars in the directions of the diagonals with displacement between, so that a star at the corner of the plate for one exposure was brought to the centre of the plate for another, and conversely, as indicated in the diagram, and the distances between the two images of a number of stars nearly in the same straight line were measured. These measures showed that, though there might be a distortion amounting to 2″ at a distance of 1° from the centre, the different magnitudes of the stars and consequent difference in the

images made it impracticable to obtain a trustworthy correction to the measures depending on the distance from the centre of the plate.



The coordinates of the reference stars were measured in two positions of the plate (in the second position turned in its own plane through 180°), and where there were two exposures the two images were measured by separate measurers and the mean taken. The planet's image or images were measured twice, in direct and reversed positions of the plate.

The measured coordinates of the reference stars were compared with the standard coordinates derived from their right ascensions and declinations, and linear corrections

$$ax + by + c \text{ and } dx + ey + f$$

were obtained to the measured coordinates. These corrections were applied to the measured coordinates of the planet, and its apparent right ascension and declination deduced. The constants c and f are arbitrary, depending on the assumed right ascension and declination of the centre of the plate in the computation of the standard coordinates; but a and e, when corrected for differential refraction and aberration, give the *scale* value, while d and e, similarly corrected, give the orientation.

The values of the correction to the scale (assumed to be 1^{mm} to $1'$) as derived from the separate determinations of a and e for each plate, and the corrections for orientation of each plate expressed in circular measure ($=-b=d$) are given in Table I.

The mean of thirty-two determinations from a gives ·01109 as the correction to the assumed scale, while the mean of the thirty-two determinations from e gives ·01117. The resulting

focal length is $(1 + \cdot 0111)^{mm} \times \text{cosec } 1'$, that is $3^m \cdot 4760$, or 11 feet 4·85 inches. The scale is almost exactly $\frac{1}{90}$th larger than the scale of 1^{mm} to $1'$ adopted for the Astrographic Chart.

The discordances between the two determinations of scale value and of orientation from the measures in the two directions x and y are exhibited in the fourth and seventh columns of Table I. The mean values of these discordances are $\pm \cdot 00028$ and $\pm \cdot 00039$ $(= \pm 1'' \cdot 3)$. The large values of the discordances in the orientation as determined from the measures in the two directions shown on the plates taken on September 20, 21, 23, and October 3, is probably due to the fact that no *réseau* was printed on these plates, and their measurement was consequently more difficult.

On February 28 and March 14, in addition to exposures of five and six minutes, which showed the planet, an additional short exposure of forty seconds was also given. The plate constants were determined separately for the long and short exposures, and the differences of the coordinates of a number of stars near the centre of the plate were also measured. Thus a comparison was obtainable between the plate constants determined in the two ways. The following table shows satisfactory accordance between the results :—

	$a-a'$	$b-b'$	$c-c'$	$d-d'$	$e-e'$	$f-f'$
Feb. 28	$-\cdot 00024$	$-\cdot 00015$	$+\cdot 03''$	$-\cdot 00009$	$-\cdot 00034$	$+\cdot 27''$
Mar. 14	$-\cdot 00003$	$-\cdot 00004$	$-\cdot 18''$	$-\cdot 00012$	$-\cdot 00015$	$+\cdot 09''$

Table II. gives the lengths of the exposures on the different nights, the number of reference stars used, the mean discordances of the measured coordinates corrected linearly, and the "standard coordinates" derived from the tabular places of these stars. In addition the approximate coordinates of the planet and of the mean of the reference stars are also given.

Comparison of columns 3 and 4 with 5 and 6 shows that the position of the planet on the plate is never far from the mean of the stars. Any errors in the scale and orientation will only have a small effect on the determination of the "standard coordinates" (and therefore of the deduced right ascension and declination) of the planet.

The mean values of the discordances shown in columns 8 and 9 of Table II. are $\pm^s \cdot 061$ and $\pm 0'' \cdot 76$. These represent the combined effect of errors in the measures (including distortion) and in the tabular places of the stars. As the average number of reference stars is 16 per plate, and the planet is near their mean position, the probable error of its position arising from these causes is $\pm^s \cdot 013$ and $\pm'' \cdot 16$.

TABLE I.

Plate Constants.

Date.	Correction to Scale Value. a	e	$a-e$ (in units of fifth decimal place)	Correction for Orientation. b	d	$b+d$ (in units of fifth decimal place)
1898.						
Sept. 20	−·01048	−·01099	+51	+·00931	−·00801	+130
21	−·01106	−·01120	+14	+·00055	+·00063	+118
23	−·01103	−·01124	+22	−·00260	+·00391	+131
Oct. 3	−·01099	−·01120	+21	−·00087	+·00207	+120
Nov. 3	−·01122	−·01063	−59	−·01117	+·01061	−56
Dec. 7	−·01080	−·01113	+33	−·01426	+·01369	−57
9	−·01072	−·01112	+40	−·01107	+·01083	−24
1899.						
Jan. 10	−·01123	−·01139	+16	−·01444	+·01438	−6
25	−·01166	−·01098	−68	−·01595	+·01606	+11
26	−·01060	−·01083	+23	−·01498	+·01498	0
27	−·01140	−·01142	+2	−·01469	+·01415	−54
Feb. 2	−·01102	−·01144	+42	−·01279	+·01233	−46
22	−·01137	−·01128	−9	−·00842	+·00858	+16
22	−·01152	−·01156	+4	−·01396	+·01408	+12
24	−·01105	−·01102	−3	−·01374	+·01351	−23
24	−·01120	−·01095	−25	−·01436	+·01437	+1
25	−·01129	−·01107	−22	−·01519	+·01500	−19
27	−·01116	−·01126	+10	−·01602	+·01675	+73
27	−·01118	−·01122	+4	−·01448	+·01483	+35
28	−·01142	−·01159	+17	−·01588	+·01533	−55
28	−·01118	−·01125	+7	−·01573	+·01542	−31
Mar. 5	−·01157	−·01110	−47	−·01165	+·01143	−22
5	−·01148	−·01121	−27	−·01435	+·01420	−15
9	−·01096	−·01152	+56	−·01833	+·01848	+15
11	−·01062	−·01134	+72	−·01565	+·01619	+54
14	−·01066	−·01112	+46	−·01564	+·01591	+27
14	−·01064	−·01098	+34	−·01560	+·01603	+43
24	−·01077	−·01098	+21	−·02005	+·01999	−6
24	−·01085	−·01095	+10	−·01292	+·01277	−15
27	−·01118	−·01093	−25	−·01493	+·01492	−1
27	−·01126	−·01108	−18	−·01647	+·01664	+17
31	−·01128	−·01093	−35	−·01560	+·01564	+4
Mean	−·01109	−·01115	±28	...	...	±39

TABLE II.

Date.	Exposure.	Approx. Coords. of Planet. R.A.	Decl.	Approx. Coords. of Mean of Reference Stars. R.A.	Decl.	No of Stars.	Mean discordance of tabular and measured Coords. R.A.	Decl.
1898.		′	′	′	′		s	″
Sept. 20	20m	− 0·1	− 1·3	−11·0	+ 0·2	14	± ·046	± 0·51
21	20m	− 2 0	+ 3·5	− 8·5	+ 4·0	15	± ·060	± 0·66
23	15m	− 0·4	− 2·1	0·0	− 1·4	16	± ·044	± 0·60
Oct. 3	10m & 5m	+ 4·5	− 2·0	+10·5	+ 0·3	16	± ·044	± 0·66
Nov. 3	20m	+19·7	+ 2·3	− 4·2	−12·2	7	± ·038	± 0·51
Dec. 7	5m & 7m	− 7·5	− 1·5	+ 4·0	−12·5	8	± ·044	± 0·57
9	5m & 6m	− 7·8	−15·2	+ 0·6	−14·3	10	± ·054	± 0·90
1899.								
Jan. 10	5m & 4m	− 3·6	+ 1·2	− 0·4	+ 1·4	22	± ·050	± 0·66
25	4m & 6m	− 3·8	+ 3·2	−20·3	0·0	13	± ·101	± 0·75
26	4m & 6m	− 4·1	+ 2·2	+ 4·2	+ 1·6	15	± ·062	± 0·63
27	4m & 6m	− 7·5	+ 0·6	+ 2·3	+13·4	14	± ·067	± 0·51
Feb. 2	4m & 6m	−10·6	+ 3·0	−13·4	+ 2·0	18	± ·051	± 0·69
22	5m	− 5·3	+ 4·5	+ 1·5	+ 2·4	15	± ·097	± 0·84
22	5m	− 7·0	+ 2·5	− 0·6	+ 0 3	15	± ·072	± 0·87
24	4m	− 2·4	+ 2·0	− 1·9	− 8·4	22	± ·079	± 0·54
24	4½m	− 2·5	+ 3·2	− 1·2	−10·9	21	± ·062	± 0·69
25	5m	− 3·8	+ 4·3	+ 6·6	− 9 6	23	± ·087	± 0·81
27	5m	− 5·4	+ 2·7	+ 3 0	+ 6·7	14	± ·087	± 1·17
27	6m	+ 1·8	+ 3·8	+ 7·7	− 0·6	14	± ·068	± 0·81
28	6m & 5m	− 3·3	+ 1·6	+ 1·7	+ 4·8	14	± ·075	± 1·17
28	40s	...	...	+ 1·4	+ 3·7	14	± ·068	± 0·81
Mar. 5	5m	+ 2·7	+ 1·2	+ 0·2	− 8·3	19	± ·065	± 1·26
5	6m	+ 2·7	+ 1·9	− 0·1	− 7·6	19	± ·067	± 1·35
9	6m & 5m	+ 0·9	− 6·4	− 3·2	−22·4	9	± ·078	± 0·75
11	6m & 5m	− 7·6	− 9·4	+ 0·5	− 4·4	11	± ·053	± 0·42
14	5m & 4m	+ 1·4	+ 1·9	+13·2	+ 5·4	17	± ·058	± 0·87
14	40s	...	...	+13·2	+ 4·4	17	± ·058	± 1·08
24	5m	+ 3·2	+ 3·4	+ 5·3	−17·5	18	± ·056	± 0·51
24	5m	+ 1·3	+ 2·5	+ 5·6	−16·4	17	± ·036	± 0·57
27	5m	− 4·8	+ 3·1	+ 6·2	+ 4·1	21	± ·038	± 0·78
27	6m	− 8·5	+ 1·0	+ 2·0	+ 2·0	21	± ·056	± 0·81
31	6m	− 8·8	+ 2·5	+ 4·0	+ 4·8	16	± ·041	± 0·66
						Mean	± ·061	± 0·76

The right ascensions and declinations of the planet and the mean times of observation are given in Table III.

TABLE III.

Date.	G.M.T.	Apparent R.A.	Apparent Decl.	Log. Δ.	Corr. for Parx. R.A.	Corr. for Parx. Decl.
	h m s	h m s	° ′ ″		s	″
Sept. 20	9 20 6	20 37 32·39	− 6 21 20·8	9·9400	+0·08	+8·6
21	8 39 17	20 37 7·68	− 6 21 12·3	9·9430	+0·01	+8·5
23	7 49 1	20 36 26·32	− 6 20 43·7	9·9492	−0·07	+8·4
Oct. 3	7 58 14	20 35 59·57	− 6 13 59·5	9·9811	+0·02	+7·8
Nov. 3	8 15 36	21 1 4·39	− 4 47 51·2	0·0747	+0·16	+6·1
Dec. 7	6 39 44	21 58 19·74	− 0 49 25·7	0·1429	+0·12	+5·0
9	5 24 41	22 2 15·07	− 0 30 56·4	0·1464	+0·04	+5·0
Jan. 10	6 11 27	23 14 30·46	+ 5 39 3·0	0·1890	+0·14	+4·2
25	6 19 43	23 53 9·29	+ 9 5 51·6	0·2015	+0·15	+3·9
26	6 5 49	23 55 49·01	+ 9 19 57·6	0·2021	+0·15	+3·8
27	6 22 33	23 58 33·08	+ 9 34 25·6	0·2029	+0·16	+3·8
Feb. 2	6 9 36	0 15 2·42	+11 0 43·9	0·2066	+0·15	+3·7
22	7 0 19	1 14 18·37	+15 49 2·4	0·2152	+0·20	+3·6
22	7 13 28	1 14 20·10	+15 49 9·5	0·2152	+0·21	+3·6
24	6 51 8	1 20 34·05	+16 16 46·8	0·2158	+0·20	+3·5
24	7 4 51	1 20 35·87	+16 16 53·7	0·2158	+0·20	+3·6
25	7 38 59	1 23 50·45	+16 31 1·2	0·2161	+0·22	+3·7
27	8 3 29	1 30 17·37	+16 58 34·6	0·2166	+0·23	+3·8
27	8 16 2	1 30 18·75	+16 58 39·9	0·2166	+0·23	+3·8
28	7 5 49	1 33 22·61	+17 11 32·2	0·2168	+0·21	+3·5
28	7 5 49	1 33 22·61	+17 11 31·9	0·2168	+0·21	+3·5
Mar. 5	7 33 8	1 49 48·90	+18 17 41·4	0·2179	+0·22	+3·6
5	7 44 34	1 49 50·47	+18 17 47·2	0·2179	+0·22	+3·6
9	7 12 14	2 3 11·73	+19 7 54·0	0·2188	+0·21	+3·5
11	7 16 32	2 10 1·79	+19 32 13·4	0·2192	+0·22	+3·5
14	7 20 22	2 20 24·73	+20 7 24·9	0·2197	+0·22	+3·5
14	7 20 22	2 20 24·75	+20 7 24·7	0·2197	+0·22	+3·5
24	7 37 43	2 56 11·46	+21 51 42·1	0·2213	+0·23	+3·5
24	7 48 39	2 56 13·03	+21 51 46·3	0·2213	+0·23	+3·5
27	7 34 36	3 7 14·07	+22 18 23·8	0·2217	+0·23	+3·4
27	7 48 9	3 7 16·37	+22 18 27·4	0·2217	+0·23	+3·5
31	7 48 35	3 22 13·88	+22 50 19·9	0·2222	+0·23	+3·5

Indications of the accuracy of the above results may be obtained as follows :—

(i.) The observations from September 20 to December 9 have been given in the November, December and January numbers of the *Monthly Notices*. The results there given were obtained from an entirely different series of measures from those used in the present determination; in the earlier measures the point considered as the centre of an image of a star at some distance from the centre of the field was taken systematically nearer the *coma* than in the present measures. The differences between the two methods of measurement give the following differences of right ascension and declination:—

Date.	R.A.	Decl.
	s	"
1898 Sept. 20	−·04	−0·3
21	+·04	−0·2
23	+·01	+0·3
Oct. 3	+·12	−0·2
Nov. 3	+·14	+0·1
Dec. 7	−·01	−0·1
9	+·01	+1·1

(ii.) The differences between the positions obtained from two plates taken on the same night when correction is made for the movement of the planet in the interval are

Date.	R.A.	Decl.
	s	"
1899 Feb. 22	+·09	−0·3
24	+·02	−0·8
27	−·24	−1·5
Mar. 5	+·03	−0·3
24	−·09	0·0
27	(+·53)*	−0·6

(iii.) When the plate constants are determined from the subsidiary short exposure, and from the differences of the coordinates of the images of a number of stars near the centre, the differences between the determinations of the right ascensions and declination of the planet are

Date.	R.A.	Decl.
	s	"
1899 Feb. 28	0·00	−0·3
Mar. 14	+0·02	−0·2

In addition to the errors which would be shown in these comparisons, there may be systematic errors of the catalogues employed. No investigation has been made of these and no corrections have been applied; but in most cases these are probably small.

* The image of the planet was very faint on the second plate taken on March 27.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the years 1896, 1897, *and* 1898.

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The measures were made with a bifilar position-micrometer on the 28-inch refractor, aperture 28 inches, focal length 28 feet. The power generally used was 670, but when the definition permitted a power of 1030 was used for observing very close pairs. A blue glass shade was employed to diminish the light and irradiation when bright stars were observed. The observations were made in variously coloured fields or in a dark field with illuminated wires. The initials in the last column are those of the observers, viz. :—

D.	Mr. Dyson.	C.	Mr. Cowell.
L.	„ Lewis.	B.	„ Bryant.
W.B.	„ Bowyer.	D.E.	„ Edney.
P.M.	„ Melotte.	N.	„ Niblett.

Micrometric Observations of Double Stars.

Star's Name.	R.A. 1900.	N.P.D. 1900.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1890+	Obs.
	h m	° ′	°	″				
Σ 3062 ...	0 1	32 10	339·2	1·42	1	6·9 8·0	8·978	B.
β 1014 ...	0 2	58 53	304·1	1·15	3	7·0 12·5	7·937	L.
β 255 ...	0 6	62 10	107·5	0·44	1	7·5 8·4	6·827	L.
			91·7	0·53	3	...	7 885	W.B.
			99·3	0·45	3	...	7·885	L.
OΣ 2 A.B.	0 8	63 35	41·4	0·77	1	6·5 8·0	6·805	W.B.
			36·6	0·52	2	...	6·816	L.
			34·4	0·64	3	...	7·844	W.B.
			33·5	0·47	2	...	7·896	L.
			36·9	0·56	2	...	8·877	L.
			34·6	0·69	3	...	8·908	W.B.
h 1007 (OΣ A.C.)	0 8	63 35	227·2	17·82	1	6·5 9·6	7·898	W.B.
			226·8	17·62	1	...	7·909	L.
			225·7	17 42	1	...	8·778	W.B.
			225·8	17·91	1	...	8·868	L.
OΣ 4 ...	0 10	54 8	146·0	0·48	1	7·5 8·0	7·953	L.
			146·9	0·48	1	...	8·950	W.B.
β 1093 ...	0 15	79 46	39·8	0·31	1	7·3 8·2	6·927	L.
			49·2	0·50	1	...	7·958	L.
			60·9	0·39	1	...	8·885	L.